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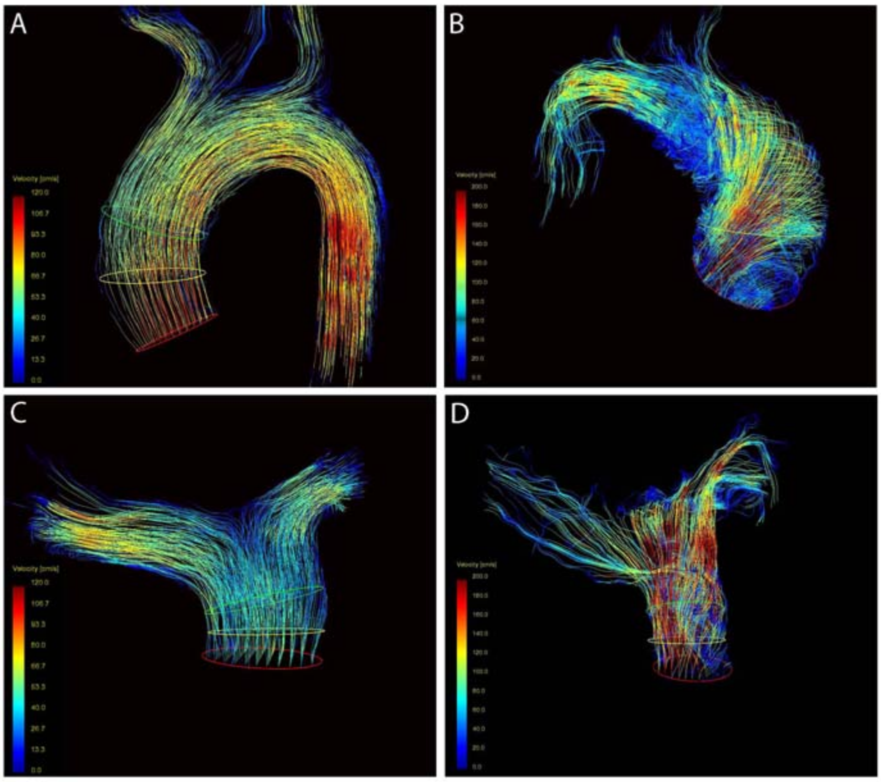
Four-dimensional velocity encoded magnetic resonance imaging improves blood flow quantification in congenital heart disease

Nordmeyer S.(1), Riesenkampff E.(1),Kropf S.(2), Berger F. (1),Kuehne T.(1)
Deutsches Herzzentrum Berlin, Berlin, Germany (1); Institut für Biometrie und Medizinische Informatik, Magdeburg, Germany (2)

Purpose: Valvar stenosis causes accelerated and often complex non-laminar flow patterns that are difficult to assess quantitatively using two-dimensional velocity encoded magnetic resonance imaging (2D VEC MRI). We sought to evaluate the use of 4D VEC MRI for visusalizing flow patterns and measuring flow velocities and volumes in complex flow conditions as frequently encountered in congenital heart disease.
Materials and Methods: Peak velocities (Vmax) and flow volumes (SV) were quantified by 2D and 4D VEC MRI in volunteers (n=7) and patients with aortic or pulmonary valve stenosis (n=17). Measurements were performed at standard planes (=level 1) by both techniques and at three further levels in the ascending aorta (levels 2-4) and two in the pulmonary trunk (levels 2-3) using 4D VEC MRI. In patients, regions of peak flow velocities were visualized by 4D VEC MRI and targeted for blood flow quantification. In all patients Vmax was also measured by Doppler echocardiography.



Results: In volunteers flow patterns were laminar. In patients there were complex flow patterns characterized by high velocity jets and vortex formation. In volunteers and patients, SV at level 1 were comparable between 2D and 4D VEC MRI, but Vmax was higher using 4D VEC MRI ($p<0.03$). When comparing flow as measured at different anatomical levels in the ascending aorta, there was a significant larger variance in SV in patients than in volunteers ($p= 0.004$). Peak flow velocity visualized by 4D VEC MRI correlated better with Doppler echocardiography than 2D VEC MRI ($r= 0.7$ vs. $r= 0.5$).
Conclusion: 4D VEC MRI, like Doppler echocardiography, can target and thus improve the assessment of peak flow velocity in valvar stenosis. In addition, 4D flow allows visualizing regions with very complex flow that might be associated with turbulences. Therefore, measurement accuracy can be potentially improved.

Figure: In healthy volunteers flow patterns along the ascending aorta and main, right and left pulmonary artery were laminar in part swirling but not turbulent (Figure A,C). In patients with aortic or pulmonary valve stenosis flow patterns showed a large variance with vortex formation, helical blood flow and presumably local turbulences (Figure B,D).